A SERIES

OF

# QUESTIONS AND EXAMPLES

RELATING TO THE SUBJECTS

TREATED OF IN THIS VOLUME.

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The following Examination Questions are divided into sections corresponding to the text, so that each section has a head-line which is the same as that of the section to which the questions refer.

No attempt should be made to answer the questions or to solve the examples until the corresponding part of the text has been carefully studied.

# TRAMWAY SYSTEMS

## EXAMINATION QUESTIONS

(1) Define (*a*) tractive effort and (*b*) tractive resistance.

(2) Name the five methods which have been used to supply current to electric tramcars.

(3) If a car increases its speed, in 15 seconds, from 5 miles per hour to 25 miles per hour, what is the average acceleration in miles per hour per second? Ans. 1·33 mi. per hr. per sec.

(4) (*a*) Distinguish between the geographical centre and the load centre of a tramway system. (*b*) How and when may these centres not be identical?

(5) Why is it not generally feasible to drive electric cars from storage batteries carried on the ca s themselves?

(6) Why does a tramcar require greater power during acceleration of speed than when running at a uniform speed?

(7) (*a*) What is understood by a gradient of 1 in 50? (*b*) What force, in addition to that necessary on a level track, is required to move a car weighing 15 tons uniformly up such a gradient? Ans. 672 lb.

(8) (*a*) What is the surface-contact system of supplying current to tramway cars? (*b*) What are the following: A yoke; a plough; a skate; and, a contact stud?

(9) In addition to overcom ng tractive resistance, what force must be applied to a car weighing 25 tons to give an acceleration of ·9 mile per hour per second? Ans. 2,295 lb.

(10) If it requires a force of 25 pounds per ton to move a car at a uniform rate on a level track, how many pounds per ton will be required to move it up a $3\frac{1}{2}$ per cent. gradient?

Ans. 103·4 lb. per ton

(11) Why is direct and not alternating current always supplied to the trolley wire or other working conductor of a tramway, even though the transmission from the generating station to a substation may be by alternating current?

(12) Summarize the principal considerations on which the best position of the power station, in regard to the tramway system which it supplies, is decided.

(13) If it requires a tractive effort of 90 pounds per ton to start a given car on the level, what is the steepest incline on which it can be started without the wheels skidding, if 70 per cent. of the weight of the car rests on the driving wheels and the adhesive force is 14 per cent. of the weight on the driving wheels?

Ans. 1 in 17, nearly

(14) (*a*) What are the special advantages of the conduit system of supplying current to tramway cars? (*b*) What are the special disadvantages of the conduit system?

(15) Sketch and describe the path of current to and from a tramcar worked by the overhead trolley system, if the trolley wire is supplied at the voltage of the main generator.

(16) If a car, with its passengers, weighs 12 tons, and the tractive resistance on the level is 20 pounds per ton, find the horsepower required to propel the car up a 5 per cent. gradient at a speed of 8 miles per hour. Ans. 33·8 H.P.

(17) On a certain 500-volt tramway system six single-truck cars are to carry 45 passengers each and eight double-truck cars are to carry 75 passengers each. The single-truck cars weigh 9 tons and the double-truck cars weigh 15 tons each; the passengers may be allowed for at 15 per ton, and the total loss between power station and the cars amounts to 20 per cent. of the power required for the cars. (*a*) What is the average current per car? (*b*) How much power will be required at the cars? (*c*) How much power must be generated at the station?

Ans. (*a*) 18 amperes and 30 amperes
(*b*) 174 K.W.
(*c*) 208·8 K.W.

# TRAMWAY TRACKS

## EXAMINATION QUESTIONS

(1) What are the most common gauges of track used for tramway work?

(2) (*a*) Why are car wheels and rails made with bevelled tread? (*b*) What are the standard weights per yard for rails of British Standard section?

(3) What composition of steel is recommended by the Engineering Standards Committee for track rails?

(4) What are tie-bars, rail anchors, and fish-plates?

(5) Name four methods of making joints in track rails.

(6) What is a compound curve, and why does it give smoother riding than a simple curve?

(7) Describe the thermit process of welding rail joints.

(8) What important point must be observed in laying out curves on double tracks?

(9) (*a*) What is rail corrugation? (*b*) How may the corrugation be removed?

(10) Describe the method of making electrically welded joints in track rails.

(11) What special construction is adopted at points and cross-overs in tramway track in order to prevent excessive wear?

(12) Calculate the resistance of 2 miles of double track consisting of rails weighing 100 pounds per yard, all four rails being in parallel. Ans. ·022 ohm

(13) Describe the method of making a Falk cast-welded joint in a track rail.

(14) What are the average values of the resistances of cast-welded, electrically welded, and thermit-welded rail joints in terms of lengths of solid rail ?

(15) Enumerate the different types of paving in use for tramway tracks.

(16) (*a*) What are rail bonds, and why are they necessary ? (*b*) Describe three methods of expanding bond terminals into contact with the rail web.

(17) What is electrolysis, and under what conditions does it occur ?

(18) Describe the principles of action of (*a*) the Siemens bond tester, (*b*) the telephonic bond tester, and (*c*) the Everett-Edgecumbe bond tester.

(19) (*a*) For what purpose are negative feeders used ? (*b*) What is a negative booster, and how does it effect economy in feeder cables ?

(20) Describe a method of electrically welding bonds to track rails.

# TRAMWAY OVERHEAD WORK

## EXAMINATION QUESTIONS

(1) What are the two positions in which trolley wires are erected with regard to the track ?

(2) Explain the construction of the tubular poles generally used for tramway work.

(3) In what three ways are trolley wires generally supported ?

(4) What are guard wires, and why are they used ?

(5) Enumerate the advantages of the span-wire construction.

(6) Explain how trolley wires are supported, so as to present a smooth surface to the trolley wheel.

(7) (*a*) Of what material are trolley wires usually made ? (*b*) What material is used for trolley wires where they have to withstand heavy wear ?

(8) (*a*) When are frogs used ? (*b*) What is the difference between fixed and movable frogs ?

(9) Describe the construction of a straight-line hanger.

(10) (*a*) What special cross-sections of trolley wire are sometimes used, and why ? (*b*) Are they entirely successful in practical working ?

(11) What are double and single pull-offs, and for what are they used ?

(12) Describe the order of procedure observed when erecting span and trolley wires.

(13) Explain the construction of: (*a*) Brooklyn insulators; (*b*) globe insulators. (*c*) Why will these insulators hold up the span wires even if their insulation is entirely destroyed?

(14) (*a*) Show two methods of erecting trolley wires at curves. (*b*) How are the wires anchored?

(15) (*a*) For what purpose are section insulators used? (*b*) Describe the construction of a section insulator.

(16) Describe the method which can be used by a single operator to produce artificial respiration in a person who has apparently been killed by an electric shock.

(17) What are the functions of a positive booster?

(18) Calculate the lowest voltage received by the cars on a system with eight equally spaced cars on a 3-mile length of double track, fed at the centre. The two trolley wires are each No. 00 S.W.G. and are connected in parallel. The rails are

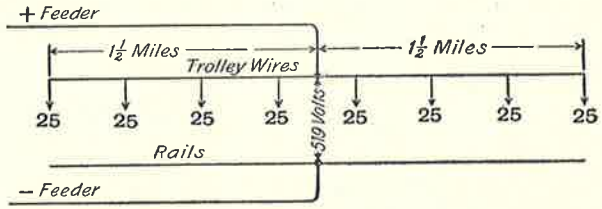


FIG. I

95 pounds per yard, and all four are in parallel. Each car is assumed to take 25 amperes. The system is arranged as shown in Fig. I, the voltage between the trolley wires and the rails at the feeding points being 519 volts. Ans. 501·15 volts

(19) What is a feeder pillar, and what switches does it contain?

(20) Describe the principle and operation of the method adopted for rapidly testing the insulating fittings used on overhead work.

# TRAMWAY CARS AND EQUIPMENT

## EXAMINATION QUESTIONS

(1) What is: (*a*) a trailer car? (*b*) a collision fender? (*c*) wheel base?

(2) State the differences between single trucks and double trucks.

(3) Describe the usual methods of lubricating trolley wheels.

(4) Compare the special conditions for which single-deck and double-deck cars, respectively, are suitable.

(5) What is the object of using car meters?

(6) Describe briefly the different forms of motor suspension.

(7) What is the best arrangement of car sheds and depots for a large tramway system serving a scattered district?

(8) State the principal functions and requirements of a car truck.

(9) What are the special uses of: (*a*) the fixed trolley head? (*b*) the swivelling head? (*c*) the self-righting head?

(10) Describe the power circuit of a single-truck car that has a controller on each platform.

(11) Describe the lighting circuit of a double-deck car.

(12) Describe briefly the Pringle trolley-standard leakage indicator.

(13) What are the special features of a compensating single truck?

(14) What is the purpose of the sliding contact sleeve as applied to a trolley head ?

(15) Describe the B.T.H. car lightning arrester.

(16) Describe the usual method of mounting and insulating resistance grids.

(17) Compare the relative properties of chilled-iron and steel-tired wheels for tramway work.

(18) Why is it usual to connect a canopy switch, automatic circuit-breaker, and fuse all in series in the trolley circuit ?

(19) Compare the relative advantages of the equal-wheel and maximum-traction trucks for different conditions of traffic and route.

(20) Describe briefly the action of the Westinghouse car circuit-breaker

# BRAKES AND BRAKE RIGGING

## EXAMINATION QUESTIONS

(1) Define (*a*) coefficient of adhesion and (*b*) coefficient of sliding friction.

(2) How can vacuum-brake exhausters be arranged to economize power when maintaining the train-pipe vacuum and to exhaust rapidly when releasing the brakes ?

(3) State clearly the conditions under which the wheels of a moving car may be locked by the application of wheel brakes.

(4) (*a*) What is rheostatic braking ? (*b*) Draw a simple diagram of connections suitable for rheostatic braking with two series motors.

(5) (*a*) Describe briefly one form of hand-brake rigging suitable for a single-truck car. (*b*) Illustrate the description by a simple sketch.

(6) (*a*) What are the three positions of the driver's combined switch and brake valve in the vacuum-brake system ? (*b*) State briefly the operation of the brake gear in each position of the switch and valve handle.

(7) If a car is stopped in a distance of 100 feet after the brakes are applied, and if it is known that the car was travelling at a speed of 25 miles per hour when the brakes were first applied, what is the retardation ? Ans. 6·73 ft. per sec. per sec.

(8) Why is an equalizing connection necessary between series motors when they are connected for rheostatic braking in the usual way ?

(9) (*a*) Name the available systems of compressed-air supply for the compressed-air braking of electrically propelled trains.

(*b*) State briefly the advantages and disadvantages of the respective air-supply systems.

(10) If the weight per axle of a certain tramcar is 8 tons and the coefficients of adhesion of the wheels and of friction of the brake blocks are ·25 and ·2, respectively, what brake pressure per wheel may be expected to produce wheel slippage ?
Ans. 11,200 lb.

(11) How is the operation of the wheel brakes affected by the use of (*a*) mechanical track brakes and (*b*) magnetic track brakes ?

(12) What is the purpose of an arch bar, or curved transverse bar, as applied to a double-truck hand-brake rigging ?

(13) Why must either the armature or the field connections of series motors be reversed when the motors are being used for rheostatic braking ?

(14) Describe the principle and the method of operation of the Westinghouse electromagnetic brake, illustrating the answer by a simple sketch.

(15) Describe a hand-brake spindle that is designed to take up the slack of the brake-chain quickly and to apply the brake blocks strongly when they are in contact with the wheels.

(16) Can a tramcar descending a hill be stopped by an electric or electromagnetic brake ? State reasons for answer.

(17) Explain why the usual arrangement of single-truck hand-brake rigging tends to apply the brake blocks more strongly on the rear than on the forward wheels.

(18) In connection with the compressed-air braking system for electric trains, describe briefly the purpose and operation of (*a*) the pump governor, (*b*) the feed-valve, (*c*) the auxiliary reservoir, and (*d*) the reservoir pipe.

(19) How does the use of the driving motors on a tramcar for electric braking affect the heating of the motors ? State reason for answer.

(20) (*a*) What is the principle of regenerative braking ? (*b*) Which class of direct-current tramway motor is suitable for regenerative braking ?

# TRAMWAY MOTORS AND CONTROLLERS

## EXAMINATION QUESTIONS

(1) (*a*) What type of armature winding is used for tramway motors ? (*b*) What are the advantages of the type of winding used ?

(2) (*a*) What is the object of mechanically interlocking the power and reversing cylinders of a tramcar controller ? (*b*) Describe briefly, with sketches, how the reverse cylinder of the Westinghouse T1 controller is prevented from moving except when the power drum is in the off-position.

(3) Compare the relative advantages of series-wound and shunt-wound motors for traction work.

(4) If the spur wheel of a certain reduction gear has 74 teeth and the pinion has 18 teeth, what is the numerical value of the gear ratio ? Ans. 4·11

(5) Explain the distinction between rheostatic and magnetic braking.

(6) (*a*) What is the star wheel of a controller ? (*b*) What is its purpose ?

(7) How is the rated output of a traction motor determined ?

(8) Explain as simply as possible the principle of regenerative control.

(9) (*a*) What is a magnetic blow-out ? (*b*) Why are blow-out magnets necessary ?

(10) Why are motor cut-out switches provided on most series-parallel controllers ?

(11) What advantage has the series-parallel method of control over the rheostatic method ?

(12) Calculate the tractive effort of a motor when it is developing a torque of 470 pound-feet if it drives through a reduction gear the pinion of which has 18 teeth and the spur wheel 74 teeth, if the car wheels are 30 inches in diameter.

Ans. 1,546 lb., nearly

(13) Explain the action of the metallic-shield blow-out used on the Dick-Kerr controller.

(14) What will be the armature speed, in revolutions per minute, of the motor in question 12, when the car speed is 10 miles per hour ? Ans. 461 R.P.M.

(15) Why are the pole pieces of traction motors usually laminated ?

(16) What are the advantages of fitting interpoles in a traction motor ?

(17) What are the relative advantages of oil and grease lubrication for the bearings (*a*) of the motor armature, and (*b*) of the car axle ?

(18) Explain how four motors are usually arranged for use with a series-parallel controller.

(19) Why are the armature leads interchanged in connecting to the reversing drums of the controllers at opposite ends of the car ?

(20) Describe fully the purpose and the method of connection of a lightning arrester on a tramcar.

# DIRECT-CURRENT RAILWAYS

(PART 1)

## EXAMINATION QUESTIONS

(1) (*a*) Some railways have both third and fourth conductor rails ; explain why this is done, and its advantages. (*b*) Where on the track are these conductor rails usually placed ?

(2) The efficiency of transmission on a certain electric railway from power house to the train is assumed to be 80 per cent. and the efficiency of the motor equipment is 75 per cent. What is the cost per brake horsepower-hour developed by the motors if the electric energy is purchased from the power house at ·5d. per kilowatt-hour ? Ans. ·6215d.

(3) Make sketches showing simple methods of sectionalizing (*a*) a trolley wire and (*b*) a third-rail conductor. (*c*) What is a train section ?

(4) A train weighs 100 tons and accelerates at the rate of 3 feet per second per second, the brakes being applied when it is travelling at 20 miles per hour ; another train of similar weight accelerates at one-half this rate and brakes are applied when it is travelling at $28\frac{1}{2}$ miles per hour. What is the kinetic energy of each train when the brakes are applied ? Ans. { 2,992,170 ft.-lb. / 6,077,357 ft.-lb.

(5) What advantage is there in supplying a train with current at a pressure of 1,100 volts as against 550 volts ?

(6) What is the usual limit of weight on the driving axles of locomotives, and why is it less on electric-motor coaches ?

(7) What tractive resistance, in pounds per ton, should be allowed for rolling stock : (*a*) for ordinary goods wagons ? (*b*) for

coal trucks and small wagons? (*c*) Why is it more economical to run coaches in trains rather than singly?

(8) Mention some of the factors that vary the amount of energy used by an electric train.

(9) What is the tractive resistance of a 9-coach train that weighs 200 tons when travelling at 20 miles an hour if the area of the coach front is 100 square feet? The constant for track friction is to be taken at 4 and the constant for journal friction at ·12. Ans. 7·52 lb. per ton

(10) The train-mileage of a certain railway is 4,000 per day. Half the trains weigh 140 tons each, and the other half 70 tons each. Allowing 70 watt-hours per ton-mile, what is the daily cost of electric energy if it is supplied at ·4d. per kilowatt-hour? Ans. £49

(11) A train weighing 120 tons runs at 21·6 miles per hour at the end of the acceleration period of 18 seconds. The rotational acceleration is taken as one-tenth of the translational acceleration, and tractive resistance is 10 pounds per ton; find the horsepower developed by the motors. Ans. 1,000 H.P., nearly

(12) (*a*) Point out the differences between conditions on electric railways and tramways. (*b*) Define regeneration as applied to traction conditions.

(13) (*a*) Compare the acceleration of steam and electric trains. (*b*) What are the advantages of quick acceleration?

(14) (*a*) What is meant by the term coefficient of adhesion? (*b*) What is the maximum value for retardation with all wheels braked if the coefficient of adhesion is $\frac{1}{6}$?

(15) (*a*) What is the relation between forces for rotational and for translational acceleration? (*b*) What effect have curves on the tractive resistance of a train?

(16) Calculate the distance apart of two substations supplying current at a pressure of 580 volts to a third rail weighing 50 pounds per yard and 5 square inches cross-section. When the train is midway between the substations, it takes 1,400 amperes, and the electric pressure at that point is 500 volts. One-half the drop is in the conductor and one-half in the track rails. The conductor rail has a resistance of ·065 ohm per mile. Ans. $1\frac{3}{4}$ mi., nearly



(17) Distinguish between the character of service required from the motor equipments of (*a*) urban electric railways; (*b*) suburban electric railways; (*c*) interurban electric railways; (*d*) main-line railways; (*e*) industrial railways; (*f*) shunting locomotives.

(18) The area of an ampere-seconds curve for the motor equipment of an underground railway is found to be 54,000 ampere-seconds. The weight of the train is 125 tons, and the distance covered during each cycle is 3,960 feet; find the energy consumption, in watt-hours per ton-mile, if the pressure is 500 volts. Ans. 80 watt-hr. per ton-mi.

(19) Describe the various parts into which the cycle of operations performed by an electric train may be divided.

(20) (*a*) What are the effects of high acceleration on the generating station? (*b*) Why is it economical to use brakes in stopping a train?

# DIRECT-CURRENT RAILWAYS

(PART 2)

## EXAMINATION QUESTIONS

(1) (*a*) How are conductor rails usually connected at the joints? (*b*) Why are welded joints not used?

(2) In what way does the Dick-Kerr multiple-unit system of control differ from other multiple-unit systems?

(3) Give a summary of the Board of Trade rules regarding trains on underground railways.

(4) Describe briefly the advantage of using the coupling-rod type of electric locomotive.

(5) Give a summary of the Board of Trade rules regarding the construction of underground railways.

(6) Explain by the aid of a series of diagrams the bridge system of series-parallel control.

(7) Give the principal features of the Dick-Kerr direct multiple control.

(8) (*a*) Describe the link-suspended type of current collector. (*b*) What are the advantages of a bow collector?

(9) What is the principal difference in the action of the British Thomson-Houston and Westinghouse contactors?

(10) Describe briefly the principal types of railway motor suspensions.

(11) Explain the use of the interlocks in the Westinghouse unit-switch control system.

(12) Explain the method of rating railway motors.

(13) Explain the use of the dead man's handle used with the type M control.

(14) Explain by the aid of a diagram how the conductor rails are arranged at a junction of two tracks.

(15) (*a*) Of what materials are the insulators for conductor rails made? (*b*) Why are the rails not held rigidly to the insulators?

(16) Explain by the aid of diagrams how a motor coach in a train may be turned end for end and still retain the proper connections with the master controller.

(17) Explain the principle of the automatic-relay control.

(18) Explain the action of the metallic-shield blow-out coil.

(19) (*a*) Why is it necessary to have multiple-unit systems of control? (*b*) Explain the principle of multiple-unit control.

(20) (*a*) What are the advantages and disadvantages of gearless motors? (*b*) What two methods are used for supporting the armatures of gearless motors?

# ALTERNATING-CURRENT RAILWAYS

(PART 1)

## EXAMINATION QUESTIONS

(1) What method of overhead construction is generally used on three-phase railways?

(2) What is meant by regeneration, and in what way is it made use of in railways?

(3) What is the effect of inserting resistance in the rotor circuit of an induction motor?

(4) What considerations limit the voltage and frequency of the alternating-current supply for three-phase railways?

(5) Why will not a three-phase motor regenerate if the supply pressure fails?

(6) (*a*) Explain how two motors are connected in cascade. (*b*) What effect does this method of connection have on their speed if their shafts are coupled together mechanically? (*c*) What is the effect on the power factor?

(7) Describe the method of suspending the trolley wires adopted on the Valtellina Railway.

(8) An eight-pole motor and a six-pole motor have their shafts mechanically coupled, and are connected in cascade to a supply with a frequency of 25 cycles per second. At what speed will the combination run? Ans. 214·3 R.P.M., nearly

(9) How are the end driving wheels on the four-speed Simplon Tunnel locomotive arranged so that they can pass round curves easily ?

(10) What advantage do the new locomotives for the Simplon Tunnel Railway possess over the old locomotives for this railway ?

(11) For what reasons are squirrel-cage rotors sometimes used in motors designed to give speed variation by changing the number of poles on the stator ?

(12) What are the disadvantages of the rheostatic method of controlling the speed of a three-phase motor ?

(13) In what way are three-phase traction motors with squirrel-cage rotors started up ?

(14) What are the main differences between motors for stationary work and those for traction work ?

(15) What two considerations determine the resistance of squirrel-cage rotors for traction motors ?

(16) Describe with a simple sketch the coupling used on the motor coaches of the Valtellina Railway, to allow of relative movement between the rotor and the track wheels.

(17) Describe briefly the arrangement of circuits when the two motors of a three-speed Valtellina locomotive are connected in cascade.

(18) Explain how the driving bars are arranged on a three-phase locomotive so that the motors may be mounted on springs.

(19) Describe the method of starting a four-speed pole-changing locomotive.

(20) Describe the method of suspending the trolley wires on the Simplon Tunnel Railway.

# ALTERNATING-CURRENT RAILWAYS

(PART 2)

## EXAMINATION QUESTIONS

(1) Explain why a series motor will run in the same direction when the direction of the current passing through it is changed.

(2) How is the induced E.M.F. kept at a low value in the main field coils of a single-phase alternating-current motor ?

(3) Why are preventive reactance coils used, and what effect do they have on the amount of current carried by each contactor or unit switch ?

(4) What is the object of the compensating winding on the field frame of an alternating-current series motor ?

(5) (*a*) How is the torque produced in a compensated repulsion motor ? (*b*) How is the armature current produced ?

(6) (*a*) Explain the purpose of the resistance leads between the armature coils and the commutator on some types of alternating-current series motors. (*b*) Why are commutating poles sometimes fitted to an alternating-current series motor ?

(7) Mention two methods of operating the contactors of a unit-switch or multiple-control system.

(8) Describe briefly the Siemens catenary form of line construction.

(9) Explain why the power factor of the compensated repulsion motor increases as the speed increases.

(10) In connection with Fig. 36, state which contactors are closed on the first point of the master controller.

(11) In the single-catenary construction, how is the catenary cable usually supported and insulated ?

(12) When a bow current collector or pantograph trolley is used, what is the object of placing the trolley wire alternately to the right and the left of the centre line of the track ?

(13) How is the speed of the compensated repulsion motor controlled ?

(14) Why is the equivalent resistance of a steel rail higher for alternating current than for direct current ?

(15) What are the disadvantages of the ordinary form of double-catenary line construction, and how have these been overcome in the Siemens type of catenary suspension ?

(16) Describe the Oerlikon type of current collector.

(17) Describe the stator construction of a modern alternating-current series motor.

(18) Calculate the equivalent resistance to alternating current at a frequency of 15 cycles per second of 3 miles of double track, composed of four rails in parallel, each rail weighing 100 pounds per yard. Ans. ·1147 ohm, approximately

(19) (*a*) For what purpose are sucking transformers used ? (*b*) Explain their action by means of a simple diagram.

(20) What are deflector wires, and for what purpose are they used ?

# ELECTRIC SIGNALLING ON RAILWAYS

## EXAMINATION QUESTIONS

(1) What are home and distant signals ?

(2) What is (*a*) a telegraphic block system, and (*b*) a lock-and-block system ?

(3) Explain briefly the principle of the staff and tablet systems of operating single lines.

(4) What are automatic signals, and under what conditions are they necessary ?

(5) Explain the construction and operation of the Siemens rail contact.

(6) (*a*) What two types of block telegraph instruments are commonly used on telegraphic block systems ? (*b*) Explain their chief differences.

(7) Show with simple sketches the positions and state the indications of home and distant signals mounted on the same post.

(8) Explain the action of the Tyer signal replacer.

(9) Enumerate the advantages of operating points and signals by power.

(10) Explain how the signals are unlocked in the Sykes lock-and-block system.

(11) What is the function of the check-lock on the operating lever of power-worked points ?

(12) Explain the Sykes system of permissive signalling.

(13) Explain the operation and use of a fouling bar.

(14) Describe and explain the action of a signal selector.

(15) Describe the construction of a light indicator.

(16) Explain by the aid of a diagram the principle of track-circuit working of signals on a steam railway.

(17) Why is extra safety secured by interlocking block telegraph instruments with the signal levers ?

(18) For what purpose are signal reversers or replacers used ?

(19) (*a*) What is the advantage in allowing one block or section to overlap another ? (*b*) What is the use of the automatic train stop ?

(20) Make a diagram of the connections and describe the operation of the Westinghouse system of track circuits for electric railways.

# ANSWERS

TO THE

## QUESTIONS AND EXAMPLES

INCLUDED IN THE

EXAMINATION QUESTIONS.

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Each Key, or set of Answers, has the same section number as the corresponding set of Examination Questions. All references are to the portion of the text that bears the same section number as the Key in which the references occur, unless the title of some other part of the text is mentioned.

To be of the greatest value, the Key should be consulted sparingly, much in the same manner as a pupil would go to a teacher for assistance in solving a problem he is unable to master unaided. The Key should not be referred to except as a last resource, when the student has failed, after using every reasonable effort, to solve the example or answer the question. If used in this way, the Key will be a help and a source of encouragement in studying the various subjects comprising the Course.

# TRAMWAY SYSTEMS

(1) See Art. **36.**

(2) See Art. **10.**

(3) From Art. **43,** acceleration is the rate at which speed is increased. As in 15 sec. the speed is increased from 5 to 25 mi. per hr., the rate of increase per second, or the acceleration, is $\frac{25-5}{15} = 1{\cdot}33$ mi. per hr. per sec. Ans.

(4) (*a*) See Art. **59.**
(*b*) See Arts. **59** to **64.**

(5) See Art. **30.**

(6) See Art. **43.**

(7) (*a*) From Arts. **40** and **41,** the steepness of a gradient may be expressed by the distance travelled along it in rising an equivalent vertical distance of 1 ft. Thus, a gradient of 1 in 50 means that there is a rise of 1 ft. in a distance of 50 ft. along the gradient. Ans.

(*b*) The weight of the car $W_t = 15$ tons, and the gradient $G = \frac{1}{50}$. Then, from formula **1,** Art. **39,** the additional force required to move the car uniformly up the gradient is

$$\frac{2{,}240 \times 15 \times 1}{50} = 672 \text{ lb.} \quad \textbf{Ans.}$$

(8) See Arts. **10** to **27.**

(9) The weight $W_t$ of the car is 25 tons, and the acceleration $A = {\cdot}9$ mi. per hr. per sec. From formula **3,** Art. **46,** the additional force necessary to produce the given acceleration is

$$102 \times 25 \times {\cdot}9 = 2{,}295 \text{ lb.} \quad \text{Ans.}$$

(10) The tractive resistance equal to the tractive effort $f$ on the level is 25 lb. per ton; the gradient $G_1 = 3\frac{1}{2}$, or 3·5 per cent. From the formula in Art. **41,** the tractive effort per ton on the incline is

$$25 + 22{\cdot}4 \times 3{\cdot}5 = 25 + 78{\cdot}4 = 103{\cdot}4 \text{ lb. per ton.} \quad \textbf{Ans.}$$

(11) See Arts. **7** and **8.**



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(12) See Arts. **58** to **64**.

(13) The tractive effort $f'$, or force per ton, required to start the given car on the level is 90 lb.; the ratio $c$ of weight on the driving wheels to the total weight is $\frac{70}{100} = \cdot 7$; the ratio $b$ of the adhesive force to the weight on the driving wheels is $\frac{14}{100} = \cdot 14$. Then, from the formula in Art. **50**, the steepest incline on which the car will start is

$\cdot 7 \times \cdot 14 - \cdot 00045 \times 90 = \cdot 098 - \cdot 0405 = \cdot 0575 = \frac{1}{17}$, nearly 1 in 17. Ans.

(14) (*a*) See Arts. **14** and **15**.
(*b*) See Art. **16**.

(15) See Arts. **12** and **13**, and Fig. **1**.

(16) The tractive resistance $f$ on the level is 20 lb. per ton; the percentage of gradient $G_1 = 5$; then, from the formula in Art. **41**, the tractive effort per ton required on the gradient is $20 + 22 \cdot 4 \times 5 = 132$ lb. That is, the total force applied to the car is $12 \times 132 = 1{,}584$ lb. The speed, in miles per hour, $S = 8$. Therefore, from formula **2** in Art. **37**, the horsepower required is $8 \times 1{,}584 \div 375 = 33 \cdot 8$ H.P. Ans.

(17) (*a*) Allowing for passengers at 15 per ton, 45 passengers will weigh $\frac{45}{15} = 3$ tons, and 75 passengers will weigh $\frac{75}{15} = 5$ tons. The total weight of the single-truck car and passengers is $9 + 3 = 12$ tons, and of the double-truck car and passengers $15 + 5 = 20$ tons. Taking the average current, as given in Art. **53**, as $1 \cdot 5$ amperes per ton of weight for a 500-volt system, the current for the single-truck cars is $12 \times 1 \cdot 5 = 18$ amperes, and for the double-truck cars $20 \times 1 \cdot 5 = 30$ amperes. Ans.

(*b*) On a 500-volt system, the power required per single-truck car is $\frac{18 \times 500}{1{,}000} = 9$ K.W., and for a double-truck car is $\frac{30 \times 500}{1{,}000} = 15$ K.W. Therefore, the total power required at the cars is

$$6 \times 9 + 8 \times 15 = 54 + 120 = 174 \text{ K.W.} \quad \text{Ans.}$$

(*c*) If 20 per cent. of the power required at the cars is lost, the total loss is $\frac{174 \times 20}{100} = 34 \cdot 8$ K.W., and the total power which must be generated at the power station is $174 + 34 \cdot 8 = 208 \cdot 8$ K.W. Ans.

# TRAMWAY TRACKS

(1) See Art. **2**.

(2) (*a*) See Art. **10**.
(*b*) See Table II, Art. **7**.

(3) See Art. **4**.

(4) See Arts. **13**, **15**, and **18**.

(5) See Arts. **18** to **20**, **23**, **25**, and **30**.

(6) See Art. **41**.

(7) See Arts. **30** to **34**.

(8) See Art. **42**.

(9) (*a*) See Art. **35**.
(*b*) See Arts. **37** and **38**.

(10) See Arts. **25** to **29**.

(11) See Arts. **45** and **47**.

(12) From formula **3**, Art. **59**,

$$R_m = \frac{4 \cdot 4}{W_y}$$

In this case $W_y = 100$; therefore,

$$R_m = \frac{4 \cdot 4}{100} = \cdot 044 \text{ ohm}$$

The resistance of 2 mi. of single rail is thus $2 \times \cdot 044 = \cdot 088$ ohm, and the resistance of 4 rails in parallel is $\frac{\cdot 088}{4} = \cdot 022$ ohm. Ans.

(13) See Arts. **23** and **24**.

(14) See Arts. **62** to **64**.

(15) See Art. **50**.

(16) (*a*) See Art. **65**.
(*b*) See Arts. **67** to **70**.

(17) See Arts. **85** to **92**.

(18) (*a*) See Arts. **79** and **80.**
(*b*) See Arts. **81** to **83.**
(*c*) See Art. **84.**

(19) (*a*) See Art. **93.**
(*b*) See Art. **94.**

(20) See Arts. **71** and **72.**

# TRAMWAY OVERHEAD WORK

(1) See Art. **1.**

(2) See Arts. **7** and **8.**

(3) See Arts. **2, 4,** and **5.**

(4) See Art. **14.**

(5) See Art. **3.**

(6) See Arts. **20** and **21.**

(7) (*a*) See Art. **18.**
(*b*) See Art. **19.**

(8) (*a*) See Art. **39.**
(*b*) See Arts. **40** and **43.**

(9) See Arts. **26** and **27.**

(10) (*a*) See Art. **21.**
(*b*) See Art. **22.**

(11) See Arts. **29** and **30.**

(12) See Arts. **50** to **52.**

(13) (*a*), (*b*), and (*c*) See Arts. **31** and **32.**

(14) (*a*) and (*b*) See Art. **54** and Fig. 41.

(15) (*a*) and (*b*) See Art. **35.**

(16) See Art. **97.**

(17) See Art. **61.**

(18) The lowest voltage will be at the ends of the section. From Table VII, the resistance per mile of No. 00 S.W.G. copper trolley wire is ·4527 ohm. From Art. **83,** the distributed load behaves as if concentrated at $\frac{3}{4}$ mi. from the feeding point. Therefore, the resistance of trolley wires is $\frac{\cdot 4527 \times \cdot 75}{2} = \cdot 1698$ ohm, approximately. The drop in the trolley wires is $4 \times 25 \times \cdot 1698 = 16 \cdot 98$ volts.

From Table IX, the resistance per mile of rails weighing 95 lb. per yd. is ·0463 ohm. The resistance of the rails is therefore $\frac{\cdot 0463 \times \cdot 75}{4}$ = ·0087 ohm, approximately. The drop in the rails is $4 \times 25 \times \cdot 0087$ = ·87 volt. The total drop is 16·98 + ·87 = 17·85 volts. The lowest voltage received by the cars, therefore, is

519 − 17·85 = 501·15 volts. Ans.

(19) See Art. **57.**

(20) See Arts. **36** to **38.**

# TRAMWAY CARS AND EQUIPMENT

(1) (*a*) See Art. **1.**
(*b*) and (*c*) See Art. **4.**

(2) See Art. **6.**

(3) See Art. **36.**

(4) See Arts. **1** and **2.**

(5) See Art. **54.**

(6) See Arts. **18** to **21.**

(7) See Art. **63.**

(8) See Art. **6.**

(9) (*a*) and (*b*) See Art. **29.**
(*c*) See Art. **33.**

(10) See Art. **60.**

(11) See Art. **62.**

(12) See Arts. **58** and **59.**

(13) See Art. **9.**

(14) See Art. **32.**

(15) See Art. **57.**

(16) See Arts. **41** and **42.**

(17) See Arts. **24** and **25.**

(18) See Arts. **45** and **51.**

(19) See Art. **12.**

(20) See Arts. **47** and **48.**

# BRAKES AND BRAKE RIGGING

(1) (*a*) and (*b*) See Art. **2.**

(2) See Art. **45.**

(3) See Art. **3.**

(4) (*a*) See Art. **21.**
(*b*) See Art. **22** and Fig. **15.**

(5) (*a*) and (*b*) See Art. **7** and Fig. **3.**

(6) (*a*) and (*b*) See Art. **51.**

(7) $S = 100$ ft.; $V = 25$ mi. per hr. $= \frac{25 \times 5{,}280}{3{,}600} = 36{\cdot}7$ ft. per sec., nearly.

From the formula in Art. **5,** $100 = \frac{36{\cdot}7^2}{2\,a}$, or

$$a = \frac{36{\cdot}7^2}{2 \times 100} = 6{\cdot}73 \text{ ft. per sec. per sec.} \quad \text{Ans.}$$

(8) See Art. **22.**

(9) (*a*) and (*b*) See Arts. **34** to **37.**

(10) The weight per wheel $W = \frac{8 \times 2{,}240}{2} = 8{,}960$ lb.; $\mu = {\cdot}25$. Then, from the formula in Art. **2,** $F = {\cdot}25 \times 8{,}960 = 2{,}240$ lb. From Art. **3,** the wheel slippage may be expected to commence when $F = F' = 2{,}240$ lb. But $\mu' = {\cdot}2$. Therefore, the pressure of the brake block, or blocks, on each wheel will be

$$P = \frac{2{,}240}{{\cdot}2} = 11{,}200 \text{ lb.} \quad \text{Ans.}$$

(11) (*a*) and (*b*) See Arts. **15** and **25.**

(12) See Art. **9.**

(13) See Art. **22.**

(14) See Arts. **26, 27,** and Fig. **18.**

(15) See Art. **13** and Fig. **8.**

(16) See Art. **23.**

(17) See Art. **8.**

(18) (*a*) See Art. **39.**
(*b*) See Art. **43.**
(*c*) See Arts. **42** and **44.**
(*d*) See Art. **38.**

(19) See Art. **24.**

(20) (*a*) and (*b*) See Art. **24.**

# TRAMWAY MOTORS AND CONTROLLERS

(1) (*a*) and (*b*) See Art. **4.**

(2) (*a*) See Art. **54.**
(*b*) See Art. **87.**

(3) See Arts. **2** and **3.**

(4) See Art. **11.** In the case given, the ratio is $\frac{74}{18} = 4{\cdot}11$. Ans.

(5) See Art. **79.**

(6) (*a*) and (*b*) See Art. **52.**

(7) See Art. **6.**

(8) See Arts. **95** and **96.**

(9) (*a*) and (*b*) See Arts. **55** and **56.**

(10) See Arts. **67** and **68.**

(11) See Art. **64.**

(12) From the formula in Art. **19,** $F = \frac{24\ F'\ r\ n'}{d''\ n}$. In the case given, $F'\ r = 470$, $n' = 74$, $d'' = 30$, $n = 18$. Then,

$$F = \frac{24 \times 470 \times 74}{30 \times 18} = 1{,}546 \text{ lb., nearly.}$$ Ans.

(13) See Arts. **93** and **94.**

(14) By transposing the formula in Art. **21,** it is found that the speed of the armature $s = \frac{336{\cdot}1 \times n' \times S}{n \times d''}$. In the case given, $n' = 74$, $n = 18$, $S = 10$, $d'' = 30$. Substituting these values,

$$s = \frac{336{\cdot}1 \times 74 \times 10}{18 \times 30} = 461 \text{ R.P.M.}$$ Ans.

(15) See Art. **1.**

(16) See Art. **47.**

(17) (*a*) and (*b*) See Art. **8.**

(18) See Art. **77.**

(19) See Art. **61.** The armature wires are reversed on one controller, as shown in Fig. 26 of the text.

(20) See Art. **76.**

# DIRECT-CURRENT RAILWAYS

## (PART 1)

(1) (*a*) See Art. **50.**
(*b*) See Art. **44.**

(2) See Art. **63.** The combined efficiency is $\cdot 80 \times 75$ per cent. $= 60$ per cent. Therefore, for every brake horsepower-hour, the power house must deliver $\dfrac{746}{\cdot 6 \times 1{,}000} = 1 \cdot 243$ K.W.-hr., which will cost

$$1 \cdot 243 \times \cdot 5 = \cdot 6215\text{d.} \quad \text{Ans.}$$

(3) (*a*) See Art. **54.**
(*b*) See Art. **56.**
(*c*) See Art. **55.**

(4) From the formula in Art. **36,** if one train runs at 20 mi. per hr., or $\dfrac{20 \times 5{,}280}{60 \times 60} = 29 \cdot 33$ ft. per sec., its kinetic energy is

$$\frac{100 \times 2{,}240 \times 29 \cdot 33^2}{2 \times 32 \cdot 2} = 2{,}992{,}170 \text{ ft.-lb.} \quad \text{Ans.}$$

If the other train runs at $28\frac{1}{2}$ mi. per hr., or $\dfrac{28 \cdot 5 \times 5{,}280}{60 \times 60} = 41 \cdot 8$ ft. per sec., its kinetic energy is $\dfrac{100 \times 2{,}240 \times 41 \cdot 8^2}{2 \times 32 \cdot 2} = 6{,}077{,}357$ ft.-lb., or more than double that of the first train. Ans.

(5) See Art. **47.**

(6) See Art. **41.**

(7) (*a*) and (*b*) See Art. **11.**
(*c*) See Art. **12.**

(8) See Art. **35.**

(9) From Art. **10,** $A = 4$, $B = \cdot 12$, $C = \dfrac{\cdot 00035 \times 100\ (7 + 9)}{200}$ $= \cdot 0028$. Therefore, by the formula in Art. **10**, the tractive resistance

$$D = 4 + (\cdot 12 \times 20) + (\cdot 0028 \times 20^2) = 7 \cdot 52 \text{ lb. per ton.} \quad \text{Ans.}$$

(10) See Art. **34.** The total ton-mileage is (140 × 2,000) + (70 × 2,000) = 420,000. The energy consumption per day will therefore be 420,000 × 70 = 29,400,000 watt-hr. At ·4d. per K.W.-hr. this gives

$$\frac{\cdot 4 \times 29{,}400{,}000}{1{,}000 \times 240} = £49. \quad \text{Ans.}$$

(11) From Art. **29,** the rate of acceleration is $\frac{21 \cdot 6}{18} = 1 \cdot 2$ mi. per hr. per sec. From formula **3,** Art. **16,** $P = 102 \times 1 \cdot 2 = 122 \cdot 4$ lb. per ton. Therefore, the total pull of translational acceleration is 122·4 × 120 = 14,688 lb. The pull from rotational acceleration is $\frac{1}{10} \times 14{,}688$ = 1,469 lb. The pull to overcome tractive resistance is 10 × 120 = 1,200 lb. The sum of these is 17,357 lb. A speed of 21·6 mi. per hr. is $\frac{21 \cdot 6 \times 5{,}280}{60}$ ft. per min. Therefore, the horsepower is

$$\frac{5{,}280 \times 17{,}357 \times 21 \cdot 6}{33{,}000 \times 60} = 1{,}000, \text{ nearly.} \quad \text{Ans.}$$

(12) (*a*) See Art. **1.**
(*b*) See Art. **5.**

(13) (*a*) See Art. **14.**
(*b*) See Art. **15.**

(14) (*a*) See Art. **21.**
(*b*) See Table III.

(15) (*a*) See Art. **17.**
(*b*) See Art. **13.**

(16) See Art. **49.** The conductor rail will carry 700 amperes from each substation, so that the drop per mile is 700 × ·065 = 45·5 volts. The drop between substation and train is 80 volts, one-half of which drop is in the conductor and one-half in the track rails. Therefore, the distance between substations must be about $\frac{2 \times 40}{45 \cdot 5} = 1\frac{3}{4}$ mi., nearly. Ans.

(17) See Art. **6.**

(18) The voltage of supply is 500; therefore, as in Art. **33,** the watt-hours will be

$$\frac{500 \times 54{,}000}{60 \times 60} = 7{,}500$$

Now, 3,960 ft. is $\frac{3}{4}$ mi., so the ton-miles per cycle will be 125 × ·75, and the energy consumption will be $\frac{7{,}500}{125 \times \cdot 75} = 80$ watt-hr. per ton-mi. Ans.

(19) See Art. **7.**

(20) (*a*) See Art. **38.**
(*b*) See Art. **37.**

# DIRECT-CURRENT RAILWAYS

## (PART 2)

(1) (*a*) and (*b*) See Art. **109.**
(2) See Art. **93.**
(3) See Art. **38.**
(4) See Art. **9.**
(5) See Art. **117.**
(6) See Arts. **77** and **78.**
(7) See Art. **97.**
(8) (*a*) See Art. **28.**
(*b*) See Art. **33.**
(9) See Arts. **54** and **79.**
(10) See Arts. **19** and **20.**
(11) See Art. **84.**
(12) See Art. **2.**
(13) See Art. **59.**
(14) See Art. **113** and Fig. **51.**
(15) (*a*) and (*b*) See Art. **114.**
(16) See Arts. **45** and **48.**
(17) See Art. **74.**
(18) See Art. **91.**
(19) (*a*) and (*b*) See Art. **44.**
(20) (*a*) See Art. **3.**
(*b*) See Art. **4.**

# ALTERNATING-CURRENT RAILWAYS

(PART 1)

(1) See Art. **94.**

(2) See Arts. **9** to **11.**

(3) See Art. **16.**

(4) See Arts. **4** and **5.**

(5) See Art. **13.**

(6) (*a*) See Arts. **19** and **20.**
(*b*) See Arts. **21** and **22.**
(*c*) See Art. **30.**

(7) See Arts. **95** and **96.**

(8) See Art. **21.**

$$N = \frac{120 \sim}{P + P'} = \frac{120 \times 25}{8 + 6} = 214{\cdot}3 \text{ R.P.M., nearly.} \quad \text{Ans.}$$

(9) See Art. **87.**

(10) See Art. **93.**

(11) See Art. **40.**

(12) See Art. **17.**

(13) See Art. **44.**

(14) See Art. **3.**

(15) See Arts. **42** and **43.**

(16) See Art. **59.**

(17) See Art. **77.**

(18) See Art. **66.**

(19) See Art. **92.**

(20) See Arts. **100** and **101.**



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# ALTERNATING-CURRENT RAILWAYS

(PART 2)

(1) See Art. **3.**

(2) See Art. **4.**

(3) See Arts. **62** and **63.**

(4) See Arts. **5** to **8.**

(5) (*a*) See Art. **46.**
(*b*) See Art. **45.**

(6) (*a*) See Arts. **20** and **21.**
(*b*) See Art. **22.**

(7) See Art. **60.**

(8) See Art. **131.**

(9) See Art. **49.**

(10) See Art. **100.**

(11) See Art. **121.**

(12) See Art. **116.**

(13) See Arts. **52** and **53.**

(14) See Art. **135.**

(15) See Arts. **125** and **131.**

(16) See Arts. **119** and **120.**

(17) See Arts. **37** and **38.**

(18) From formula **3**, Art. **136**, the equivalent resistance of 1 mi. of single rail is $R_{15} = \frac{15{\cdot}3}{100} = {\cdot}153$ ohm, and that of 3 mi. of track, consisting of four rails in parallel, is

$$\frac{{\cdot}153 \times 3}{4} = {\cdot}1147 \text{ ohm, approximately.} \quad \text{Ans.}$$

(19) See Art. **138.**

(20) See Art. **130.**

# ELECTRIC SIGNALLING ON RAILWAYS

(1) See Arts. **3** and **4.**

(2) (*a*) See Art. **7.**
(*b*) See Art. **17.**

(3) See Art. **47.**

(4) See Art. **57.**

(5) See Art. **20.**

(6) See Art. **7.**

(7) See Art. **5.**

(8) See Art. **27.**

(9) See Art. **48.**

(10) See Art. **34.**

(11) See Art. **50.**

(12) See Art. **39.**

(13) See Art. **22.**

(14) See Arts. **31** and **32.**

(15) See Art. **28.**

(16) See Art. **66.**

(17) See Art. **17.**

(18) See Art. **24.**

(19) (*a*) See Art. **62.**
(*b*) See Art. **63.**

(20) See Arts. **67** to **69.**



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NOTE.—All items in this Index refer first to the section and then to the page of the section. Thus, *Adhesion*, §63, *p34*, means that *Adhesion* will be found on page 34 of section 63. When there are several items having the same key word, this is, for brevity, omitted after the first reference, and the other items are indented, or set in, from the left margin, to indicate this omission, which never consists of more than one word. Thus, under the key word *Air* is found the indented item, *supply, Systems of ;* this is read *Systems of air supply*, the capitalization of *Systems* denoting the first word of the reference.


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